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UTILITY PATENT APPLICATION TRANSMITTAL

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Attorney Docket No. MI22-587

Total Pages 30

First Named Inventor or Application Identifier

J. Dennis Keller et al.

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APPLICATION ELEMENTS		ADDRESS TO:	Assistant Commissioner for Patents Box Patent Application Washington, DC 20231
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1. <input checked="" type="checkbox"/> Fee Transmittal Form (Submit an original, and a duplicate for fee processing)	6. <input type="checkbox"/> Microfiche Computer Program (Appendix)		
2. <input checked="" type="checkbox"/> Specification [Total Pages 23] (preferred arrangement set forth below)	7. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)		
<ul style="list-style-type: none"> - Descriptive title of the Invention - Cross References to Related Applications - Statement Regarding Fed sponsored R & D - Reference to Microfiche Appendix - Background of the Invention - Brief Summary of the Invention - Brief Description of the Drawings (if filed) - Detailed Description - Claim(s) - Abstract of the Disclosure 			
3. <input checked="" type="checkbox"/> Drawing(s) (35 USC 113) [Total Sheets 4]	a. <input type="checkbox"/> Computer Readable Copy		
4. Oath or Declaration [Total Pages 2]	b. <input type="checkbox"/> Paper Copy (identical to computer copy)		
a. <input checked="" type="checkbox"/> Newly executed (original or copy)	c. <input type="checkbox"/> Statement verifying identity of above copies		
b. <input type="checkbox"/> Copy from a prior application (37 CFR 1.63(d)) (for continuation/divisional with Box 17 completed) [Note Box 5 below]			
i. <input type="checkbox"/> DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).			
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 Continuation Divisional Continuation-in-part (CIP) of prior application No: _____

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NAME	Lance R. Sadler 7/17/98		
ADDRESS	Wells, St. John, Roberts, Gregory & Matkin, P.S. 601 West First Ave., Suite 1300		
CITY	Spokane	STATE	WA
COUNTRY	U.S.A.	TELEPHONE	(509) 624-4276
			FAX (509) 838-3424

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FEE TRANSMITTALNote. Effective October 1, 1997.
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Application Number	Unknown
Filing Date	Filed Herewith
First Named Inventor	J. Dennis Keller et al.
Group Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	MI22-587

METHOD OF PAYMENT (check one)1. The Commissioner is hereby authorized to charge indicated fees and credit any over payments to:Deposit Account Number 23-0925
Deposit Account Name Wells, St. John et al. Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17 Charge the Issue Fee Set in 37 CFR 1.18 at the Mailing of the Notice of Allowance2. Payment Enclosed: Check Money Order Other**FEE CALCULATION****1. FILING FEE**

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
101	790	201	395 Utility filing fee
106	330	206	165 Design filing fee
107	540	207	270 Plant filing fee
108	790	208	395 Reissue filing fee
114	150	214	75 Provisional filing fee
SUBTOTAL (1)			(\$ 790)

2. CLAIMS	Extra	Fee from below	Fee Paid
Total Claims 40	-20 = 20	X 22	= 440
Independent Claims 7	- 3 = 4	X 82	= 328
Multiple Dependent Claims 0	X 0		= 0

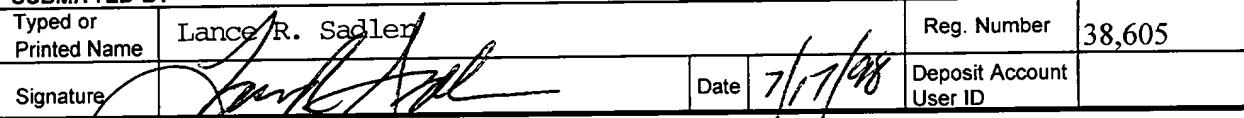
Large Entity Fee Code (\$)

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description
103	22	203 11 Claims in excess of 20
102	82	202 41 Independent claims in excess of 3
104	270	204 135 Multiple dependent claim
109	82	209 41 Reissue independent claims over original patent
110	22	210 11 Reissue claims in excess of 20 and over original patent
SUBTOTAL (2)		

3. ADDITIONAL FEES

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
105	130	205 65 Surcharge - late filing fee or oath	0
127	50	227 25 Surcharge - late provisional filing fee or cover sheet	0
139	130	139 130 Non-English specification	0
147	2,520	147 2,520 For filing a request for reexamination	0
112	920*	112 920* Requesting publication of SIR prior to Examiner action	0
113	1,840*	113 1,840* Requesting publication of SIR after Examiner action	0
115	110	215 55 Extension for reply within first month	0
116	400	216 200 Extension for reply within second month	0
117	950	217 475 Extension for reply within third month	0
118	1,510	218 755 Extension for reply within fourth month	0
128	2,060	228 1,030 Extension for reply within fifth month	0
119	310	219 155 Notice of Appeal	0
120	310	220 155 Filing a brief in support of an appeal	0
121	270	221 135 Request for oral hearing	0
138	1,510	138 1,510 Petition to institute a public use proceeding	0
140	110	240 55 Petition to revive - unavoidable	0
141	1,320	241 660 Petition to revive - unintentional	0
142	1,320	242 660 Utility issue fee (or reissue)	0
143	450	243 225 Design issue fee	0
144	670	244 335 Plant issue fee	0
122	130	122 130 Petitions to the Commissioner	0
123	50	123 50 Petitions related to provisional applications	0
126	240	126 240 Submission of Information Disclosure Stmt	0
581	40	581 40 Recording each patent assignment per property (times number of properties)	40
146	790	246 395 Filing a submission after final rejection (37 CFR 1.129(a))	0
149	790	249 395 For each additional invention to be examined (37 CFR 1.129(b))	0
Other fee (specify) _____			0
Other fee (specify) _____			0
* Reduced by Basic Filing Fee Paid			SUBTOTAL(3) (\$ 40)

SUBMITTED BY

Typed or Printed Name	Lance R. Sadler	Reg. Number	38,605
Signature		Date	7/17/98

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1105488-0156

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION FOR LETTERS PATENT

* * * * *

**Methods Of Enhancing Data Retention Of A
Floating Gate Transistor, Methods Of Forming
Floating Gate Transistors, And Floating Gate
Transistors**

* * * * *

INVENTORS

**J. Dennis Keller
Roger R. Lee**

ATTORNEY'S DOCKET NO. MI22-587

EL054830156

1 **TECHNICAL FIELD**

2 This invention relates to floating gate transistors and methods of
3 forming the same. This invention also relates to methods of enhancing
4 data retention of floating gate transistors.

5

6 **BACKGROUND OF THE INVENTION**

7 Floating gate transistors are utilized in some semiconductor
8 memory cells. One type of memory cell that uses a floating gate
9 transistor is a flash erasable and programmable read only memory
10 (EPROM). A floating gate transistor typically includes a tunnel
11 dielectric layer, a floating gate, an interlayer dielectric and a control
12 gate or word line. Source/drain regions are formed operatively adjacent
13 the floating gate and within semiconductive substrate material. A
14 floating gate transistor can be placed in a programmed state by storing
15 charge on the floating gate of the floating gate transistor. Typically,
16 a large voltage, e.g. 25 volts, between the control gate and the
17 substrate allow some electrons to cross the interlayer dielectric and
18 charge the floating gate. The "data" retention" of a floating gate
19 transistor refers to the ability of the transistor to retain its charge over
20 a period of time. Charge can be lost, undesirably, through electron
21 migration from the floating gate through various adjacent materials.
22 One problem which has confronted the industry is electron migration
23 through the interlayer dielectric material immediately above the floating
24 gate. The thickness of the interlayer dielectric material has an impact

1 on the ability of a floating gate to retain its charge. Thinner regions
2 of the interlayer dielectric material provide undesired migration paths for
3 electrons to leave the programmed floating gate relative to other thicker
4 regions of the interlayer dielectric material. Hence, non-uniformity in
5 the thickness of the interlayer dielectric material is undesirable.

6 A contributing factor to a non-uniformly thick interlayer dielectric
7 material is the presence of a large number of grain boundaries at the
8 interlayer dielectric/floating gate interface. Conductive doping of the
9 floating gate, as is desirable, undesirably increases the number of
10 interface grain boundaries, which in turn, increases the chances of
11 having a non-uniformly thick interlayer dielectric.

12 This invention grew out of concerns associated with improving the
13 data retention characteristics of floating gate transistors.

14

15 SUMMARY OF THE INVENTION

16 Floating gate transistors and methods of forming the same are
17 described. In one implementation, a floating gate is formed over a
18 substrate. The floating gate has an inner first portion and an outer
19 second portion. Conductivity enhancing impurity is provided in the
20 inner first portion to a greater concentration than conductivity enhancing
21 impurity in the outer second portion. In another implementation, the
22 floating gate is formed from a first layer of conductively doped
23 semiconductive material and a second layer of substantially undoped
24 semiconductive material. In another implementation, the floating gate

1 is formed from a first material having a first average grain size and a
2 second material having a second average grain size which is larger than
3 the first average grain size.

5 **BRIEF DESCRIPTION OF THE DRAWINGS**

6 Preferred embodiments of the invention are described below with
7 reference to the following accompanying drawings.

8 Fig. 1 is a diagrammatic sectional view of a semiconductor wafer
9 fragment at one processing step in accordance with the invention.

10 Fig. 2 is a view of the Fig. 1 wafer fragment at a processing
11 step subsequent to that shown by Fig. 1.

12 Fig. 3 is a view of the Fig. 1 wafer fragment at a processing
13 step subsequent to that shown by Fig. 2.

14 Fig. 4 is a view of the Fig. 1 wafer fragment at a processing
15 step subsequent to that shown by Fig. 3.

16 Fig. 5 is a view of the Fig. 1 wafer fragment at a processing
17 step subsequent to that shown by Fig. 4.

18 Fig. 6 is a view of the Fig. 1 wafer fragment at a processing
19 step subsequent to that shown by Fig. 5.

20 Fig. 7 is a view of the Fig. 1 wafer fragment at a processing
21 step subsequent to that shown by Fig. 6.

22 Fig. 8 is a view of the Fig. 1 wafer fragment at a processing
23 step subsequent to that shown by Fig. 7.

1 **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

2 This disclosure of the invention is submitted in furtherance of the
3 constitutional purposes of the U.S. Patent Laws "to promote the
4 progress of science and useful arts" (Article 1, Section 8).

5 Referring to Fig. 1, a fragmentary portion of a semiconductor
6 wafer is shown generally at 10 and comprises a semiconductive
7 substrate 12. As used in this document, the term "semiconductive
8 substrate" is defined to mean any construction comprising semiconductive
9 material, including, but not limited to, bulk semiconductive materials
10 such as a semiconductive wafer (either alone or in assemblies comprising
11 other materials thereon), and semiconductive material layers (either alone
12 or in assemblies comprising other materials). The term "substrate" refers
13 to any supporting structure, including, but not limited to, the
14 semiconductive substrates described above.

15 Referring to Fig. 2, a layer 14 is formed over substrate 12 and
16 constitutes a tunnel oxide layer.

17 Referring to Fig 3, a layer 16 is formed over substrate 12. In
18 a preferred implementation, layer 16 constitutes a polysilicon layer which
19 is formed to a first thickness t_1 . Preferably, the polysilicon of layer 16
20 is undoped as formed and is subsequently doped, as through ion
21 implantation, with conductivity enhancing impurity to a desired degree.
22 According to one aspect, layer 16 is doped with a suitable impurity
23 which is sufficient to define a sheet resistance of between 300 ohm/sq.
24 and 400 ohm/sq. According to another aspect, first layer 16 is doped

1 with an impurity concentration which is greater than or equal to
2 about $1 \times 10^{18} \text{ cm}^{-3}$. An exemplary concentration is between
3 about $1 \times 10^{18} \text{ cm}^{-3}$ and $1 \times 10^{20} \text{ cm}^{-3}$, or greater. A suitable and
4 preferred dopant or impurity is phosphorous. When phosphorous is
5 utilized, the preferred sheet resistance is between about 600 ohm/sq.
6 and 700 ohm/sq.

7 Alternately considered, layer 16 constitutes a first material or
8 silicon-containing volume which is formed over the substrate and doped
9 with a suitable impurity concentration to define a first average grain
10 size. Accordingly, such silicon-containing volume has a first average
11 grain boundary area per unit volume. An exemplary grain size is
12 between about 50-100 nm, or about 10-25 grain boundaries in an erase
13 area of $0.2 \mu\text{m}^2$ to $0.4 \mu\text{m}^2$.

14 Referring to Fig. 4, a second layer 18 is formed over the
15 substrate 12 and first layer 16. Preferably, layer 18 is formed directly
16 atop layer 16 and to a second thickness t_2 . Preferably, second layer 18
17 constitutes a material such as polysilicon or amorphous silicon which is
18 substantially undoped relative to first layer 16. The term "substantially
19 undoped" as used within this document will be understood to mean
20 having an impurity concentration which is less than $1 \times 10^{18} \text{ cm}^{-3}$. In
21 accordance with one aspect of the invention, second layer 18 constitutes
22 a second material which is formed over material of layer 16 to have
23 a second average grain size which is larger than the first average grain
24 size of layer 16. Accordingly, second layer 18 constitutes a second

1 silicon-containing volume having a second grain boundary area per unit
2 volume which is less than the first grain boundary area per unit
3 volume. An exemplary grain size is between about 100-200 nm, or
4 greater than about 25 grain boundaries in an erase area of $0.2 \mu\text{m}^2$
5 to $0.4 \mu\text{m}^2$.

6 In a preferred implementation, the material of layers 16, 18, taken
7 together, constitute material from which a floating gate of a floating
8 gate transistor will be formed. Layers 16, 18 define an aggregate or
9 combined thickness ($t_1 + t_2$). Accordingly to one aspect, the combined
10 thickness of layers 16, 18 is less than or equal to about 1000
11 Angstroms. Such combined thickness can, however, range upward to
12 around 1500 Angstroms or greater. The combined thickness can range
13 downward as well. This is especially true as advances in scalability
14 result in smaller floating gate dimensions. In one implementation, the
15 first and second thicknesses are substantially the same. Accordingly,
16 when the aggregate or combined thickness is around 1000 Angstroms,
17 individual thicknesses t_1 and t_2 would be around 500 Angstroms. In
18 another implementation, first and second thicknesses t_1 and t_2 can be
19 different from one another. Accordingly, first thickness t_1 can constitute
20 less than or equal to about 75% of the aggregate thickness. In
21 another implementation, first thickness t_1 can constitute at least 25% of
22 the aggregate or combined thickness of the floating gate. In yet
23 another implementation, layer 16 can comprise between about 25-75%
24 of the floating gate thickness. Where the aggregate thickness is

1 about 1000 Angstroms, the first thickness would be between 250-750
2 Angstroms. First thickness t_1 can be less than 550 Angstroms, or
3 between 450 Angstroms and 550 Angstroms. In another implementation,
4 the combined or aggregate thickness ($t_1 + t_2$) can equal around
5 about 500 Angstroms, with thickness t_1 being equal to around 25-50
6 Angstroms. Other relative thickness relationships are of course possible.

7 Referring still to Fig. 4, layers 16 and 18 are subjected to
8 suitable floating gate definition steps. In a first step, floating gate
9 material 16, 18 is etched into and out of the plane of the page upon
10 which Fig. 4 appears. Such effectively defines so-called floating gate
11 wings which overlie field oxide which is not specifically shown in the
12 Fig. 4 construction. The first etch partially forms a plurality of floating
13 gates having respective inner first portions (layer 16) disposed proximate
14 the substrate, and respective outer second portions (layer 18) disposed
15 over the first portions.

16 Referring to Fig. 5, substrate 12 is subjected to suitable oxidizing
17 conditions which are effective to form a first oxide layer 20 over second
18 layer 18. Layer 20 constitutes a bottom oxide layer which is formed
19 to a thickness of between about 50 Angstroms to 100 Angstroms.

20 Referring to Fig. 6, a layer 22 is formed over substrate 12 and
21 preferably constitutes a nitride layer which is formed over first oxide
22 layer 20. Substrate 12 is subsequently subjected to oxidizing conditions
23 which are sufficient to form a second oxide layer 24 over nitride
24 layer 22. Taken together, layers 20, 22, and 24 constitute an ONO

1 dielectric layer which constitutes a third layer 26 of dielectric material
2 which is formed over the second silicon-containing volume or second
3 layer 18. Other dielectric layers are possible.

4 Referring to Fig. 7, a fourth layer 28 is formed over third
5 layer 26 and comprises a conductive material. In a preferred
6 implementation, layer 28 constitutes a third layer of polysilicon which
7 is formed over second oxide layer 24 and will constitute a conductive
8 line for the floating gate transistor to be formed.

9 Referring to Fig. 8, the various layers of Fig. 7 are etched to
10 provide a plurality of floating gate transistors 30, 32, 34, and 36. Such
11 defines the remaining opposing edges of the floating gates of such
12 transistors. The floating gate transistors are also provided with
13 respective source/drain regions which are disposed laterally proximate the
14 floating gates. In the illustrated example, individual source
15 regions 38, 40 and a drain region 42 are shown. Additionally, an oxide
16 layer 44 is disposed over individual floating gates 30, 32, 34, and 36.
17 A plug 46 comprising conductive contact film material is disposed
18 operatively adjacent drain region 42 and serves to electrically connect
19 with such drain region. A barrier layer 48, metal layer 50 and a
20 passivation layer 52 are shown.

21 The above-described floating gate construction provides an
22 improved floating gate transistor which is less prone to lose its charge
23 due to electron migration from the floating gate through the dielectric
24 layer intermediate the floating gate and the overlying word line. Such

1 improvements increase the data retention characteristics of the floating
2 gate. The improvements are made possible, in part, through a more
3 uniformly thick bottom oxide layer (oxide layer 20) of the ONO
4 dielectric layer discussed above. Such a uniformly thick layer provides
5 less opportunities for electrons to migrate away from the floating gate.

6 In compliance with the statute, the invention has been described
7 in language more or less specific as to structural and methodical
8 features. It is to be understood, however, that the invention is not
9 limited to the specific features shown and described, since the means
10 herein disclosed comprise preferred forms of putting the invention into
11 effect. The invention is, therefore, claimed in any of its forms or
12 modifications within the proper scope of the appended claims
13 appropriately interpreted in accordance with the doctrine of equivalents.

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1 CLAIMS:

2 1. A method for enhancing data retention of a floating gate
3 transistor comprising:

4 forming a floating gate over a substrate, the floating gate having
5 an inner first portion and an outer second portion; and

6 providing conductivity enhancing impurity in the inner first portion
7 to a greater concentration than conductivity enhancing impurity in the
8 outer second portion.

9

10 2. The method of claim 1, wherein the forming of the floating
11 gate comprises forming the inner first portion and the outer second
12 portion to comprise polysilicon.

13

14 3. The method of claim 1, wherein the floating gate has a
15 thickness, and the forming of the floating gate comprises forming the
16 inner first portion to comprise at least 25 percent of the floating gate
17 thickness.

18

19 4. The method of claim 1, wherein the floating gate has a
20 thickness, and the forming of the floating gate comprises forming the
21 inner first portion to comprise between about 25 to 75 percent of the
22 floating gate thickness.

1 5. The method of claim 1, wherein the providing of
2 conductivity enhancing impurity in the inner first portion comprises
3 doping the inner first portion to a dopant concentration greater than
4 or equal to $1 \times 10^{18} \text{cm}^{-3}$.

5
6 6. The method of claim 1, wherein the providing of
7 conductivity enhancing impurity in the inner first portion comprises
8 doping the inner first portion to a dopant concentration of greater than
9 or equal to about $1 \times 10^{18} \text{cm}^{-3}$, with the outer second portion having
10 a dopant concentration of less than $1 \times 10^{18} \text{cm}^{-3}$.

11
12 7. The method of claim 1, wherein:
13 the forming of the floating gate comprises forming a first layer
14 of polysilicon over the substrate, the first layer defining the inner first
15 portion, and after the forming of the first layer forming a second layer
16 of polysilicon, the second layer defining the outer second portion.

1 8. The method of claim 1, wherein:

2 the forming of the floating gate comprises forming a first layer
3 of polysilicon over the substrate, the first layer defining the inner first
4 portion, and after the forming of the first layer forming a second layer
5 of polysilicon, the second layer defining the outer second portion; and

6 intermediate the forming of the first and second layers, providing
7 the conductivity enhancing impurity in the inner first portion to a
8 dopant concentration of greater than or equal to about $1 \times 10^{18} \text{ cm}^{-3}$.

9
10 9. A method of forming a floating gate transistor comprising:

11 forming a first layer of conductively doped semiconductive material
12 over a semiconductive substrate;

13 forming a second layer of substantially undoped semiconductive
14 material over the first layer;

15 forming a third layer comprising dielectric material over the
16 second layer;

17 forming a fourth layer comprising conductive material over the
18 third layer; and

19 forming a floating gate transistor comprising the first, second,
20 third, and fourth layers.

1 10. The method of claim 9, wherein the first and second layers
2 comprise a floating gate having a thickness, and the forming of the first
3 and second layers comprise forming the first layer to occupy at least 25
4 percent of the floating gate thickness.

5
6 11. The method of claim 9, wherein the first and second layers
7 comprise a floating gate having a thickness, and the forming of the first
8 and second layers comprise forming the first layer to occupy less
9 than 75 percent of the floating gate thickness.

10
11 12. The method of claim 9, wherein the forming of the first
12 layer comprises forming the first layer to have a dopant concentration
13 of greater than or equal to about $1 \times 10^{18} \text{cm}^{-3}$.

14
15 13. The method of claim 9, wherein the forming of the first
16 layer comprises:

17 forming a layer of polysilicon over the substrate; and
18 doping the polysilicon layer with phosphorous dopant material to
19 a concentration of greater than or equal to about $1 \times 10^{18} \text{cm}^{-3}$.

1 14. The method of claim 9, wherein:

2 the first and second layers comprise a floating gate having a
3 thickness, and the forming of the first and second layers comprise
4 forming the first layer to occupy less than 75 percent of the floating
5 gate thickness; and

6 the forming of the first layer comprises forming the first layer to
7 have a dopant concentration of greater than or equal to
8 about $1 \times 10^{18} \text{cm}^{-3}$.

9

10 15. A method of forming a floating gate comprising:

11 forming a first material over a substrate, the first material having
12 a first average grain size;

13 forming a second material over the first material, the second
14 material having a second average grain size, the second average grain
15 size being larger than the first average grain size; and

16 providing the first and second materials into a desired floating
17 gate shape.

18

19 16. The method of claim 15, wherein the forming of the first
20 material comprises forming conductively doped polysilicon to have a
21 sheet resistance of between 300 ohm/sq. and 400 ohm/sq..

17. The method of claim 15, wherein:

2 the forming of the first material comprises forming conductively
3 doped polysilicon to have a sheet resistance of between 300 ohm/sq.
4 and 400 ohm/sq.; and

5 the forming of the second material comprises forming polysilicon
6 to have a sheet resistance greater than 400 ohm/sq..

7
8 18. The method of claim 15, wherein the forming of the first
9 material comprises forming conductively doped polysilicon to have a
10 dopant concentration greater than or equal to about $1 \times 10^{18} \text{cm}^{-3}$.

11
12 19. The method of claim 15, wherein the forming of the second
13 material comprises forming the second material directly atop the first
14 material.

15
16 20. The method of claim 15, wherein the forming of the second
17 material comprises forming the second material directly atop the first
18 material, the first and second materials having a combined thickness of
19 less than or equal to about 1000 Angstroms, the first material having
20 an individual thickness of less than about 75 percent of the combined
21 thickness.

1 21. A method of forming a floating gate transistor comprising:
2 forming a floating gate over a substrate, the floating gate
3 comprising a first silicon-containing volume having a first grain boundary
4 area per unit volume, and a second silicon-containing volume over the
5 first silicon-containing volume having a second grain boundary area per
6 unit volume, the second grain boundary area per unit volume being less
7 than the first grain boundary area per unit volume;
8 forming a dielectric layer over the second silicon-containing
9 volume; and
10 forming a conductive line over the dielectric layer to provide a
11 floating gate transistor.

12
13 22. The method of claim 21, wherein the forming of the
14 dielectric layer comprises forming an oxide layer atop the second silicon-
15 containing volume.

16
17 23. The method of claim 21, wherein the forming of the floating
18 gate comprises:

19 forming a first layer of conductively doped polysilicon over the
20 substrate, the first layer constituting the first silicon-containing volume
21 and having a dopant concentration of greater than or equal to
22 about $1 \times 10^{18} \text{ cm}^{-3}$ and a sheet resistance of between about 300
23 ohm/sq. and 400 ohm/sq..

1 24. The method of claim 21, wherein the forming of the floating
2 gate comprises:

3 forming a first layer of conductively doped polysilicon over the
4 substrate, the first layer constituting the first silicon-containing volume
5 and having a dopant concentration of greater than or equal to
6 about $1 \times 10^{18} \text{cm}^{-3}$ and a sheet resistance of between about 300
7 ohm/sq. and 400 ohm/sq.; and

8 after forming the first layer, forming a second layer of polysilicon
9 over the first layer, the second layer constituting the second silicon-
10 containing volume and having a dopant concentration less than
11 about $1 \times 10^{18} \text{cm}^{-3}$ and a sheet resistant greater than 400 ohm/sq..

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1 25. A method of forming a floating gate transistor comprising:
2 forming a first layer of polysilicon over a substrate to a first
3 thickness;

4 doping the first layer to a degree sufficient to define a sheet
5 resistance of between 300 ohm/sq. and 400 ohm/sq.;

6 after the doping, forming a second layer of polysilicon over the
7 first layer of polysilicon to a second thickness;

8 oxidizing the substrate to form a first oxide layer over the second
9 layer of polysilicon;

10 forming a layer of nitride over the first oxide layer;

11 oxidizing the substrate to form a second oxide layer over the
12 layer of nitride;

13 forming a third layer of polysilicon over the second oxide layer;
14 and

15 etching at least some of the layers to provide a floating gate
16 transistor over the substrate.

17
18 26. The method of claim 25, wherein the first and second
19 thicknesses are substantially the same.

20
21 27. The method of claim 25, wherein the first and second
22 thicknesses are different.

1 28. The method of claim 25, wherein the first and second
2 thicknesses comprise an aggregate thickness and the first thickness
3 constitutes less than or equal to about 75 percent of the aggregate
4 thickness.

5
6 29. The method of claim 25, wherein the first thickness is less
7 than about 550 Angstroms.

8
9 30. The method of claim 25, wherein the first thickness is
10 between 450 Angstroms and 550 Angstroms.

11
12 31. The method of claim 25, wherein the forming of the second
13 layer of polysilicon comprises forming the layer to have a sheet
14 resistance which is greater than the sheet resistance of the first layer
15 of polysilicon.

1 32. A floating gate transistor comprising:
2 a substrate; and
3 a floating gate over the substrate having an inner first portion
4 and an outer second portion, the inner first portion being disposed
5 proximate the substrate and the outer second portion being disposed
6 over the inner first portion, the inner first portion containing a
7 concentration of conductivity enhancing impurity which is greater than
8 a concentration of conductivity enhancing impurity contained by the
9 outer second portion;
10 a dielectric layer disposed over the outer second portion;
11 a conductive line disposed over the dielectric layer; and
12 source/drain regions laterally proximate the floating gate.

13
14 33. The floating gate transistor of claim 32, wherein the inner
15 first portion contains an impurity concentration of greater than or equal
16 to about $1 \times 10^{18} \text{cm}^{-3}$.

17
18 34. The floating gate transistor of claim 32, wherein the inner
19 first portion contains an impurity concentration of greater than or equal
20 to about $1 \times 10^{18} \text{cm}^{-3}$, and the outer second portion contains an
21 impurity concentration of less than $1 \times 10^{18} \text{cm}^{-3}$.

1 35. The floating gate transistor of claim 32, wherein the floating
2 gate has a thickness, and the inner first portion constitutes less than
3 about 75 percent of the floating gate thickness.

4

5 36. The floating gate transistor of claim 32, wherein the floating
6 gate has a thickness, and the inner first portion constitutes less than
7 or equal to about 50 percent of the floating gate thickness.

8

9 37. A floating gate transistor comprising:

10 a substrate;

11 a floating gate over the substrate comprising a first material
12 having a first average grain size and a second material disposed over
13 the first material and having a second average grain size which is larger
14 than the first average grain size;

15 a dielectric layer disposed over the second material;

16 a conductive line disposed over the dielectric layer; and

17 source/drain regions laterally proximate the floating gate.

18

19 38. The floating gate transistor of claim 37, wherein the first
20 material has a sheet resistance of less than about 400 ohm/sq..

21

22 39. The floating gate transistor of claim 37, wherein the first
23 and second materials define an aggregate thickness and the first material
24 occupies less than 75 percent of the aggregate thickness.

1 40. The floating gate transistor of claim 37, wherein the first
2 and second material have individual respective thicknesses and the first
3 material thickness is less than the second material thickness.

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1 **ABSTRACT OF THE DISCLOSURE**

2 Floating gate transistors and methods of forming the same are
3 described. In one implementation, a floating gate is formed over a
4 substrate. The floating gate has an inner first portion and an outer
5 second portion. Conductivity enhancing impurity is provided in the
6 inner first portion to a greater concentration than conductivity enhancing
7 impurity in the outer second portion. In another implementation, the
8 floating gate is formed from a first layer of conductively doped
9 semiconductive material and a second layer of substantially undoped
10 semiconductive material. In another implementation, the floating gate
11 is formed from a first material having a first average grain size and a
12 second material having a second average grain size which is larger than
13 the first average grain size.

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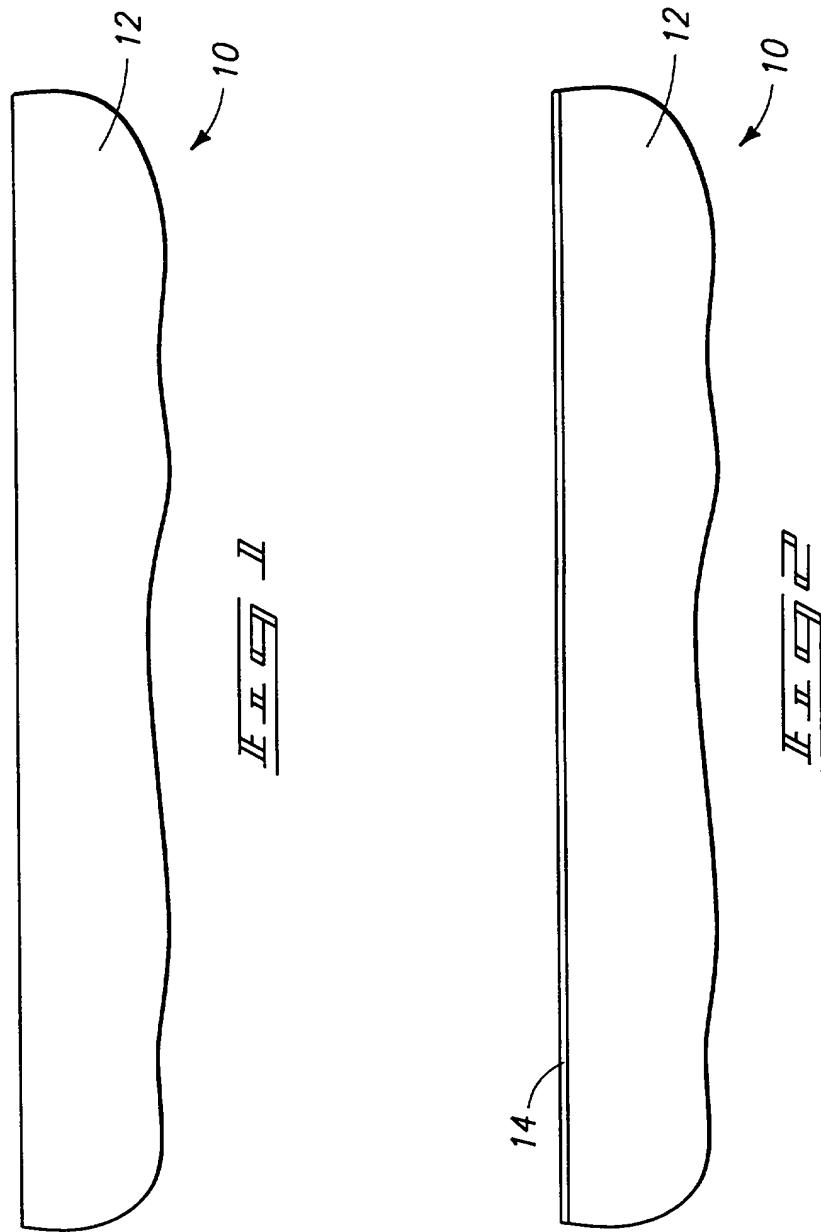
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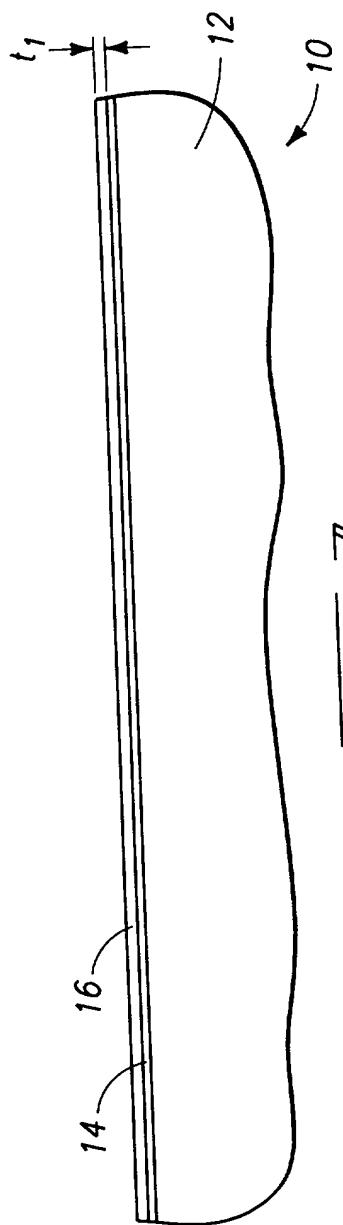
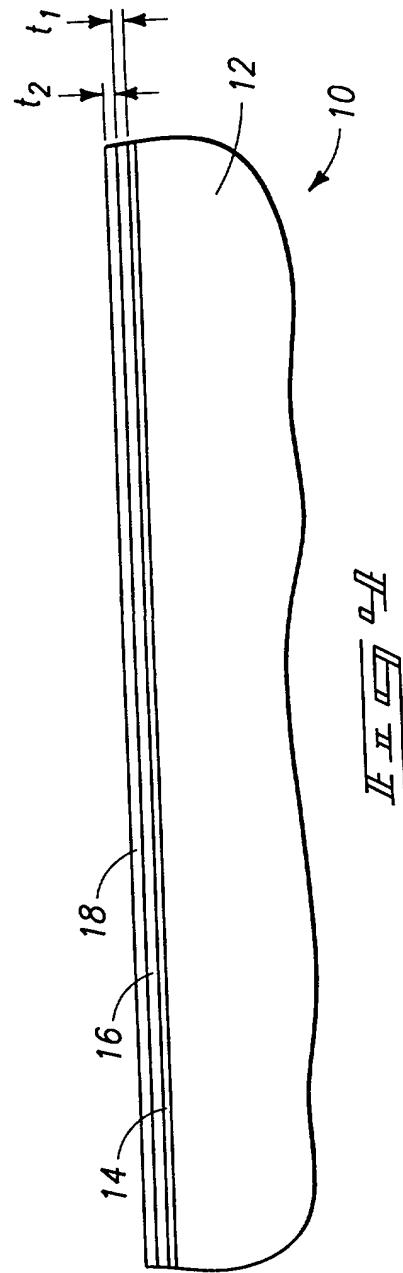
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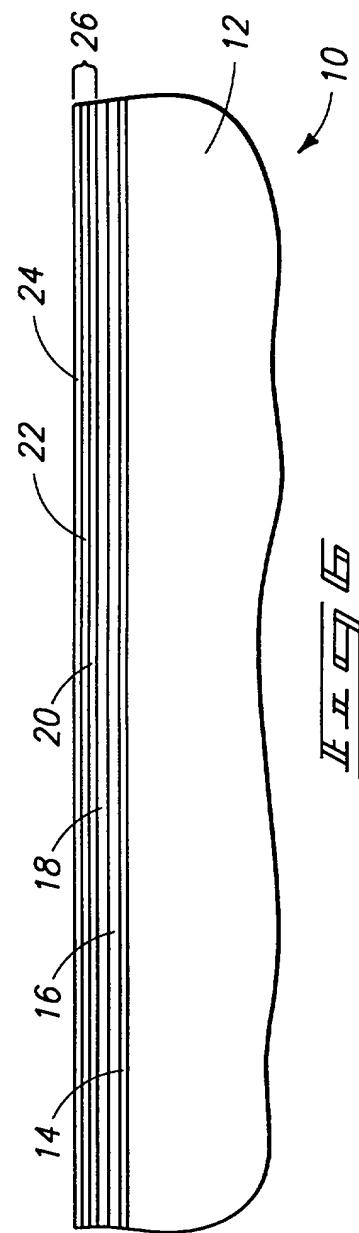
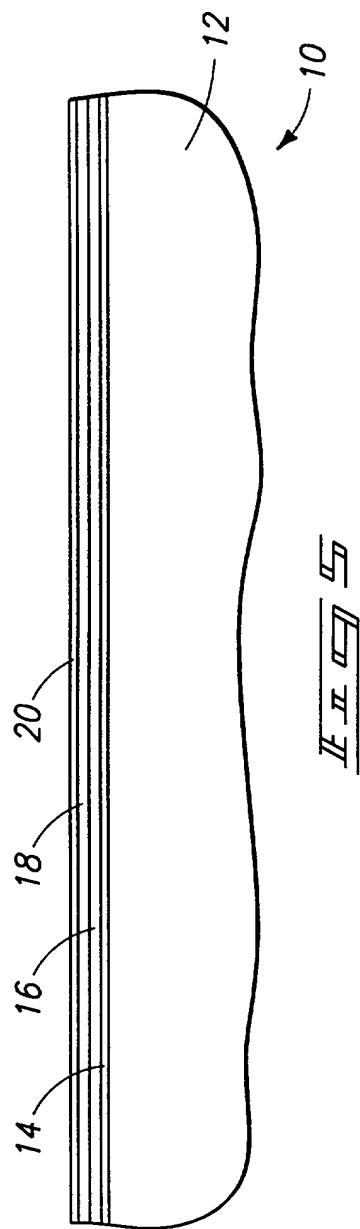
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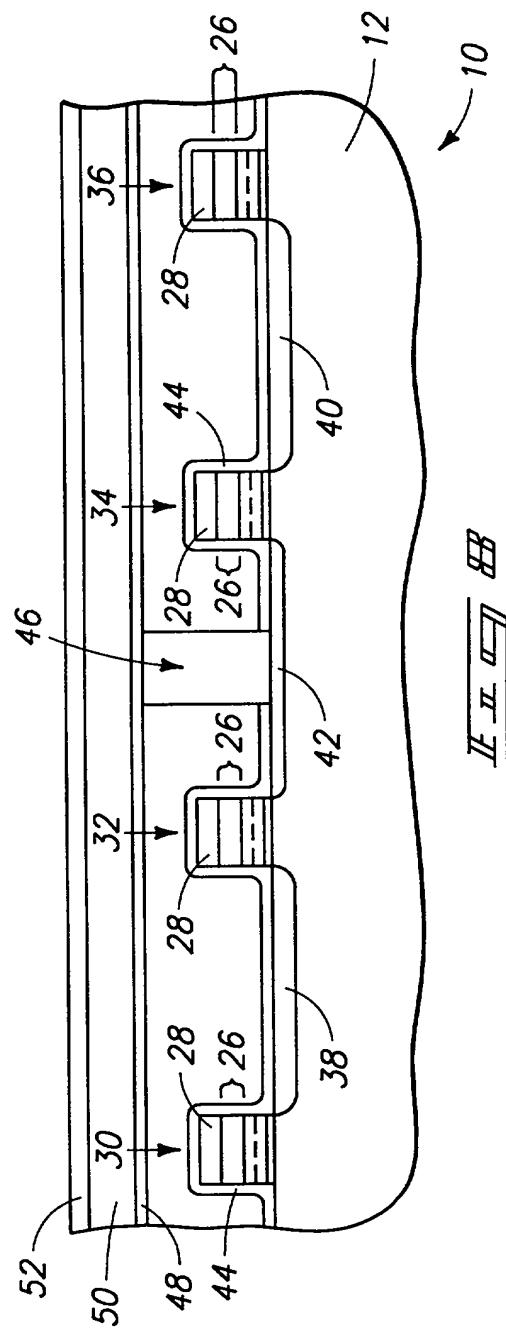
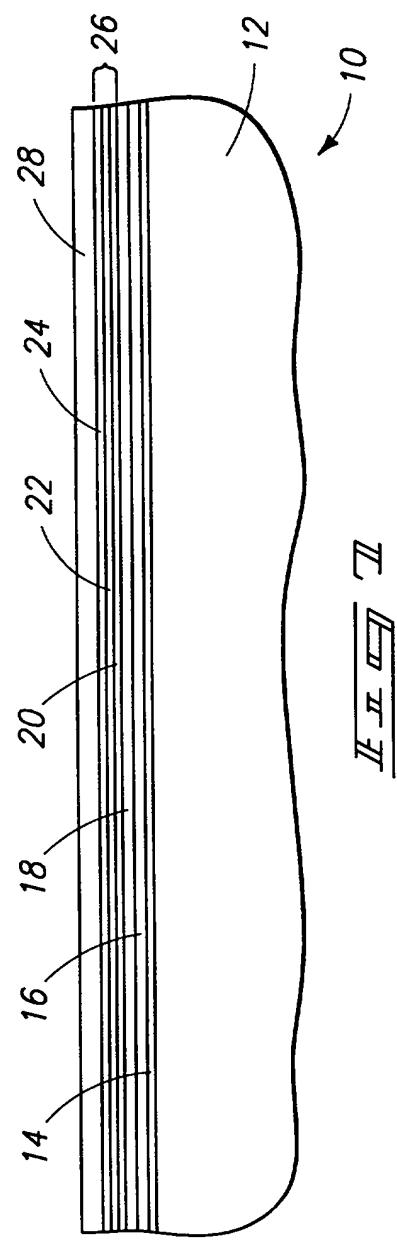
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor J. Dennis Keller et al.
Assignee Micron Technology, Inc.
Attorney's Docket No. MI22-587
Title: Methods of Enhancing Data Retention of a Floating Gate Transistor, Methods
of Forming Floating Gate Transistors, and Floating Gate Transistors

**POWER OF ATTORNEY BY ASSIGNEE AND
CERTIFICATE BY ASSIGNEE UNDER 37 CFR §3.73(b)**

To: Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

MICRON TECHNOLOGY, INC., the Assignee of the entire right, title and interest in the above-identified patent application by assignment attached hereto, hereby appoints the attorneys and agents of the firm of WELLS, ST. JOHN, ROBERTS, GREGORY & MATKIN P.S., listed as follows:

Richard J. St. John	Reg. No. 19,363
David P. Roberts	Reg. No. 23,032
Randy A. Gregory	Reg. No. 30,386
Mark S. Matkin	Reg. No. 32,268
James L. Price	Reg. No. 27,376
Deepak Malhotra	Reg. No. 33,560
Mark W. Hendrickson	Reg. No. 32,356
David G. Latwesen	Reg. No. 38,533
George G. Grigel	Reg. No. 31,166
Keith D. Grzelak	Reg. No. 37,144
John S. Reid	Reg. No. 36,369
Lance R. Sadler	Reg. No. 38,605
James D. Shaurette	Reg. No. 39,833

and also attorneys Michael L. Lynch (Reg. No. 30,871) and Lia Pappas Dennison (Reg. No. 34,095) of Micron Technology, Inc., as its attorneys with full power of substitution to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

1 The Assignee certifies that the above-identified Assignment has
2 been reviewed and to the best of Assignee's knowledge and belief, title
3 is in the Assignee.

4 Please direct all correspondence regarding this application to:

5 Wells, St. John, Roberts, Gregory & Matkin P.S.
6 Attn: Mark S. Matkin
6 601 W. First Avenue, Suite 1300
7 Spokane, WA 99201-3817

7 Telephone: (509) 624-4276
8 Facsimile: (509) 838-3424

9 MICRON TECHNOLOGY, INC.

11 Dated: 7/13/98 By: MLL
12 Name: Michael L. Lynch
13 Title: Chief Patent Counsel

1 **DECLARATION OF JOINT INVENTORS FOR PATENT APPLICATION**

2 As the below named inventor, I hereby declare that:

3 My residence, post office address and citizenship are as stated
4 below next to my name.

5 I believe I am the original, first and joint inventor of the subject
6 matter which is claimed and for which a patent is sought on the
7 invention entitled: Methods of Enhancing Data Retention of a Floating
8 Gate Transistor, Methods of Forming Floating Gate Transistors, and
9 Floating Gate Transistors, the specification of which is attached hereto.

10 I hereby state that I have reviewed and understand the contents
11 of the above-identified specification, including the claims.

12 I acknowledge the duty to disclose information known to me to
13 be material to patentability as defined in Title 37, Code of Federal
14 Regulations §1.56.

15 **PRIOR FOREIGN APPLICATIONS:**

16 I hereby state that no applications for foreign patents or inventor's
17 certificates have been filed prior to the date of execution of this
18 declaration.

19 I hereby declare that all statements made herein of my own
20 knowledge are true and that all statements made on information and
21 belief are believed to be true; and further that these statements were
22 made with the knowledge that willful false statements and the like so
23 made are punishable by fine or imprisonment, or both, under
24 Section 1001 of Title 18 of the United States Code and that such willful

false statement may jeopardize the validity of the application or any patent issued therefrom.

* * * * * * * * * *

Full name of inventor: J. Dennis Keller
Inventor's Signature: J. Dennis Keller
Date: 7/1/98

Residence: **Boise, Idaho**

Citizenship: **U.S.A.**

Post Office Address: 1863 S. Londoner Way
Boise, ID 83706

* * * * * * * * * *

Full name of inventor: **Roger R. Lee**

Inventor's Signature: Roger K
Date: 7-1-98

Residence: **Boise, Idaho**

Citizenship: U.S.A.

Post Office Address: ~~335 Raindrop
Boise, ID 83706~~

3936 N. BURNS ROAD
BURE 113 83704